Quantifiable nodes in causal diagrams

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Abstract
The quantifiable nodes of causal diagrams (e.g. RBP, DCD) — whether indicators with directly-obtained values or indices with calculated values — are dynamically related to represent a complex holon, so their appropriate handling requires both scientific rigour and understanding.

1 Introduction
Purely conceptual causal diagrams such as the reverse blueprints (RBP) of Systems Planning\textsuperscript{58} (Perdicoúlis, 2010) and the causal loop diagrams (CLD) of System Dynamics (Sterman, 2000) feature nodes that are quantifiable — i.e. able to be expressed as quantities. The grammatical class of these nodes is nouns (e.g. population, satisfaction) or noun phrases (e.g. local population, client satisfaction), and expressions in their positive version (e.g. happiness instead of unhappiness) facilitate reasoning and the identification of feedback loop polarity (Sterman, 2000, p.153).

Specialised causal diagrams such as the descriptive causal diagrams (DCD) of Systems Planning\textsuperscript{59} and the stock-and-flow diagrams (SFD) of System Dynamics include nodes similar to those of the conceptual diagrams, tailored to their particular needs — for instance, DCDs feature double-tier action (‘X’) nodes with identifiable but not necessarily quantifiable application points (§ 3.2) (Perdicoúlis, 2014b); SFDs distinguish the quantifiable nodes that are stocks (e.g. population) or flows (e.g. births per year) (Sterman, 2000, Ch.6).

Appropriate handling of the individual node values, relationships between nodes, as well as the holon they collectively represent (e.g. system, plan) requires (a) scientific rigour (e.g. precision, accuracy) regarding the language and calculations and (b) understanding, which is conditioned by rigour — Figure 1.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{rigour_understanding.png}
\caption{Rigour and understanding depend on each other}
\end{figure}
2 Node values

2.1 Direct obtention vs. calculation — indicators vs. indices

Numerical values for the quantifiable nodes are obtained either (a) directly through measurement, count, or estimate (Perdicoúlis, 2014c), in which case they are known as indicators, or (b) by calculation, in which case they are known as indices1 (Perdicoúlis and Glasson, 2011). Hence, the identification of sources (e.g. databases, publications, experts) and methodology (e.g. measurement, setup) are crucial for working with indicators, while the definition of computational relationships (i.e. equations) is essential for working with indices2.

Causal relationships in diagrams indicate but do not guarantee whether the value of a quantifiable node is obtained directly or calculated. Computational relationships expressed in equations also indicate the inputs for nodes, but such relationships are not intended to be causal — e.g. Figure 2.

![Efficiency Diagram](image)

**Figure 2** Basic definition of efficiency in a technical perspective (Perdicoúlis, 2014a)

2.2 Estimation

When direct obtention of indicator values (§ 2.1) is not possible, they may be estimated by experience3 (Perdicoúlis, 2014c) so that the related indices may be calculated — Figure 3. Estimation may also be applied directly to the indices (e.g. efficiency), bypassing their decomposition into indicators (e.g. outcome, resources) and thus providing a ‘global’ empirical value that cannot be verified.

![Efficiency Calculation](image)

**Figure 3** Calculation of efficiency by a particular set of data

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1 Variations across time, space, and cultures (e.g. disciplinary conventions) is to be expected (Perdicoúlis, 2014d)

2 The causal and computational perspectives can be presented in a combined view (Perdicoúlis, 2014b)

3 Εμπειρία [Gk]
3 Expression

3.1 Relative values

Conceptual causal diagrams such as RBP and CLD are essentially ‘reasoning exercises’ about causal relationships and operate with relative values — for instance: ceteris paribus⁴, if ‘factor A’ increases, then ‘ranking’ increases; if ‘factor A’ decreases, then ‘ranking’ decreases. Nonetheless, the mark-up of quantities next to selected nodes (e.g. Figure 4) or value charts placed by the diagram (Sterman, 2000, e.g. p.151) function as ‘quick references’ or aides-memoir (Perdicoúlis, 2014b).

![Figure 4](image-url) Relative value next to a selected RBP node, marking an objective (Z)

3.2 Absolute values — abstract vs. concrete

For specialised causal diagrams such as DCDs, the definition of the problem in ‘XYZ’ mark-up requires realistic ‘absolute’ node values and relationships (Perdicoúlis, 2014b). The nature of the DCD elements calls for differential precision — for instance, the declaration of the high-level concerns (Y) can be expressed in abstract terms (e.g. ‘strength’), while the concrete objective (Z) is conveniently defined in specific terms (e.g. ‘12-gauge’) — Figure 5.

![Figure 5](image-url) DCD node mark-up with appropriate values: abstract for Y and specific for Z

3.3 Annotation techniques

Adding values or other annotations to the nodes can be achieved with framed or plain labels (Figure 4) and alternatively with pins (Figure 5). A third alternative are compound nodes, which are most suitable for intrinsic node properties such as measurement units or data sources (Perdicoúlis, 2014b) — Figure 6.

![Figure 6](image-url) Sample compound node

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⁴ This condition indicates that the change takes place besides ‘what it would have been’ (Sterman, 2000, p.152), in the same sense as an ‘impact’ (Perdicoúlis, 2015)
4 Operations

4.1 Aggregation — generalisation/ abstraction

Indicator (and even index) nodes can be aggregated into indices — e.g. various objectives (Z) into a concern (Y), as illustrated in the complementary views of Figure 7. This operation is typically encountered in reverse blueprints (RBP).

\[ D = A \cdot B \cdot C \]

**Figure 7** Aggregation of system elements (A–C) into a more ‘inclusive’ element (D)

4.2 Specification — decomposition/ resolution

The reverse operation is also possible, albeit limited to descriptive causal diagrams (DCD): indices such as concerns (Y) or complex objectives (Z) can be explicated, analysed, decomposed, or specified through logical causality into subsequent levels of detail, as deemed necessary — Figure 8.

**Figure 8** Specification of a general or abstract concern (Y) into objectives (Z₁–Z₃)

4.3 Importance

Indices manage to synthesise sizeable portions of reality, which is convenient when a ‘zoom out’ or aggregated view is desirable — for instance, a patient’s overall health or the global efficiency of an operation. Despite its aggregation quality, though, an index is not necessarily more important than its parts — for instance, equal efficiency values may hide ‘top results’ among inferior outcomes, as illustrated in Figure 9.

\[ \text{top result} = \left( \begin{array}{c} \text{efficiency} = \frac{8\text{th level}}{4\text{ hours}} = \frac{12\text{th level}}{6\text{ hours}} = \frac{10\text{th level}}{5\text{ hours}} = 2\text{ levels/hour} \\ \text{Computational View} \end{array} \right) \]

**Figure 9** Equal efficiency with different actual outcomes
5 Discussion

Diagrammatic, textual, and mathematical languages must cater to the scientific rigour required for working with quantifiable nodes in causal diagrams — for instance, the obtention of their values (§ 2) regarding measurement, calculation, or estimate, the expression of these values (§ 3) as relative or absolute figures, and then in an abstract or concrete form, as well as basic operations (§ 4) such as aggregation and specification.

Keeping a selected set of nodes and relationships in perspective is a balancing act and helps to visualise and understand the structure and function of systems and/or plans. On the other hand, calculating ‘final’ index values is quite popular, but ‘terminal’ practice when these values cannot be decomposed to track causality. The most interesting and constructive challenges arise from bringing the two views together, as any discrepancy between causal and computational views must be resolved.

6 Conclusion

Quantifiable nodes in causal diagrams work with indices and indicators, raising scientific and cognitive issues related to measurement, reporting, and operations. Parallel causal and computational views help to seek, question, and understand structure and function, as well as to select the most important nodes together with their relationships.

References